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RESEARCH ARTICLE

Estimating the Amount of Methane Gas Generated from the Solid Waste using the Land GEM Software, Sistan and Baluchistan

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Abstract

The biodegradation of organic compounds in the waste produces different gases such as methane gas. Despite the adverse greenhouse effects of the methane, this gas has many fuel values. Since estimating the amount of methane gas produced from the waste can be an economic and useful way for more accurate control and management of waste disposal in the Sistan and Baluchistan Province, conducting this study is essential. In this research, after collecting required information such as population, growth rate, the results obtained from the physical and chemical analysis of the waste, geographic data and the desired disposal system using LandGEM software, the methane generation potential obtained from the waste disposal in the Sistan and Baluchistan Province was investigated. The results of this study showed that the methane production potential in the Sistan and Baluchistan Province is 147 m^3/ton, and if the waste disposal process was started in 2006, the methane generation would be 567 m^3/h in 2011 and by considering a 20-years period, this amount will be 3596 m^3/h in 2026. Therefore, according to the presence of adequate landfill sites in the Sistan and Baluchistan Province, it can be concluded that the controlled burial along with the gas extraction equipment in this province is a useful way for the waste management.

Keywords: *Estimating, Land GEM, Methane, Solid Waste, Sistan and Baluchistan.*

Introduction

The production of solid waste materials is the result of human activities that nowadays, due to air and water contamination, it has greatly been changed due to the lifestyle changes and the comprehensive developments in comparison with the past. By the advancement of science and technology, the production and management of solid waste materials are widely under the scientific and research consideration (1-5). One of the management methods of solid waste materials is the waste hygienic burial which can be an economic way if the performance guidance is correct so that after a while, anaerobic bacteria in different layers of buried waste produce and diffuse gases such as methane and carbon dioxide in higher amounts and hydrogen sulfide and the other nitrogen oxides in lower amounts *via* their developmental activities (6).

Therefore, since the methane gas has a very high thermal value (the thermal value of each cubic meters of methane is equal to the thermal value of one-liter kerosene), its efficiency and economic importance can be realized. Also, according to the explosion ability of methane gas due to its 5-15% condensation in the environment, the greenhouse effect which is 25-30 times the carbon dioxide gas, health risks, plant demolition, groundwater pollutions and odor problems, the importance of recycling and collecting this gas from landfill sites has increased (7).

The Sistan and Baluchistan province with an area of 187500 km^2 includes 11.4% of total area in Iran as the largest province. Regarding to the population, this province has the lowest population density but the highest population growth rate among the other provinces. The statistical data depicts that the Sistan and Baluchistan province is considered as an arid and semi-arid area due to the low rainfall, high temperature and evaporation. In this area, there is not any permanent river, and from mid-spring, the majority of surface flows are dried (8).

Nowadays, in many city of Iran, the waste management is based upon the recycling and producing the compost fertilizer, and according to the conducted research, due to the poverty of organic compounds and humidity in the waste, the lack of proper waste maintenance, the high percentage of water evaporation, and also the lack of drinking water, the compost production is an unsuccessful and inefficient method (9).

Until now, different studies have been carried out such as the research conducted by Mahvi *et al.* entitled "Calculating the amount of methane gas emission from the waste hygienic burial in Shahrood City using the LandGEM software" (10, 11), Safari *et al.* entitled "Investigating the possibility of methane pollution decrease in the urban landfills *via* the clean development mechanism in the Rasht City" (12), Talaiekhozani *et al.* entitled "Modeling of Methan Organic gaz emission reate in solid waste landfill in city of Jahrom" (13).

Since this research has not been conducted in the Sistan and Baluchistan Province yet and according to the production of biogas in the landfill between 2 to 6 months after the waste burial that this delay depends on the percentage of biodegradable organic compounds in the waste, the waste humidity and compound, the penetration of water into the landfill, and temperature (the percentage of methane in the landfill gas often reaches the steady level and maximum amounts after 6-12 months and 1-2 years, respectively) (14- 16), in this study, it has been tried to use the maximum methane energy extracted from the adequate and appropriate landfill sites.

This energy can be applied for the electricity production and using in the heating issues and etc. By using the Land GEM software as a mathematical model designed by US Environmental Protection Agency, an economic and useful method has been presented for the more appropriate control and management of waste disposal in the Sistan and Baluchistan Province.

Material and Method

So far, different methods have been carried out for calculating the amount of gas extracted from the landfill sites that in all procedures, the production of these gases are modeled. In most common models, the one or multi-step first-order equations have been used for the description of gas amounts produced in the landfills. In this cross-sectional study, the amount of methane gas generated from the landfill sites in the Sistan and Baluchistan Province has been calculated using the Land GEM software (17).

To conduct this research, first, the sampling process for the waste was done, and the quantitative and qualitative characteristics were determined. Such process was carried out by Omrani *et al.* in 2009, and since in that research the waste burial time (starting the waste burial) has been assumed the 2009 year, this step was avoided, and their results were used as depicted in Table 1 (1).

The Land GEM software has been designed based upon the first-order equation (equation 1), and this software not only can calculate the amount of methane gas produced in the landfill sites, but also estimate the amount of 46 air pollutants (18).

$$Q_{CH_4} = \sum_{i=1}^{n} \sum_{j=0.1}^{1} KL_0 \left[\frac{M_i}{10}\right] e^{-kt_{ij}} \qquad Eq\ 1$$

Q_{CH4} = Annual methane generation in the year of the calculation (m^3/year)
i = Time step counter (one year)
n = Year of the calculation - initial year of waste acceptance
j = Annual time increment (0.1 year)
k = Methane generation rate in the year (in this research, k is equal to 0.18 day^{-1} regarding to the humidity percent = 25.5% and pH = 5.2) (6)
L_0 = Methane generation potential (m^3/Mg)
Mi = Mass of waste accepted in the i^{th} year (Mg)
t_{ij} = age of the j^{th} section of waste mass Mi accepted in the i^{th} year (decimal years, e.g,. 3.2 years)

L_0=MCF×DOC× DOC_f× F×16/12× (1-OX)
MCF = Methane generation correction coefficient (0.8)

DOC = Biodegradable organic carbon in the waste (it is 0.0231 for the paper and cardboard and 0.22 for the waste)

DOC_f = The percentage of organic compounds which are interchangeable to methane and carbon dioxide gases (in this research, it is 0.83)
$DOC_f = 0.14T + 0.28$

F = The percentage of methane gas in the landfill (in this research, it is 0.57 according to the quantitative and qualitative characteristics of the waste)

OX = Oxidation in the landfill layers (in this research, it is assumed zero)
The growth rate has been calculated using equation 2.

$$P_n = P_0(1 + r)^n \qquad Eq\ 2$$

The average of annual growth rate in the Sistan and Baluchistan Province is 5.05 according to the results of General Population and Housing Census in 2004. In addition, a 20-years period has been considered in this study.

Furthermore, in this research, the proposed burial system has 8 m width, 60 m length, and 9 m depth. The annual growth of waste generation increment was considered about 2%.

Table 1: Components of waste in the province of Sistan and Baluchistan (1)

Rubber	Plant material	Glass	Metal	PET	Hard plastic	Soft plastic	Cardboard	Paper	Bread
3.1	53	2.3	4.9	1.2	3.2	6.4	5.8	4.7	3.3
household trash (Per capita)		Moisture (%)	density	C/N	C	pH	Other	Textile	Trash
504 g		25.5	182.8	22	28.1	5.2	6.4	2.2	3.6

Results

Table 2 illustrates the population growth rate in different years (the average of annual population growth rate is 5.05) and the amount of waste generated in the 20-years period.

Table 4 presents the amount of methane gas generation in different years of this period in the landfills of the Sistan and Baluchistan Province. Amount of produced pollution in landfill is shown in table 3

Table 2: Population growth with 2% waste increase per year

Years	Population	Solid weight Per year (ton)
2006	602706.00	110783.80
2007	633142.65	119967.11
2008	665116.36	129806.21
2009	698704.73	140452.27
2010	733983.32	151971.46
2011	771055.30	164435.40
2012	809994.10	177921.57
2013	8508989.80	192513.81
2014	893869.19	208302.83
2015	939009.59	225386.79
2016	986429.57	243871.88
2017	1036244.26	263873.03
2018	1088574.60	285514.58
2019	1143547.62	398931.06
2020	1201296.77	334268.04
2021	1261962.26	361683.03
2022	1325691.35	391346.47
2023	1392638.76	423442.75
2024	1462967.02	458171.41
2025	1536846.86	495748.33
2026	1614457.62	536407.13

Table 3: Pollution concentration in Zahedan landfill

Pollutions	concentration (ppmv)
NMOC	4000
1,1,1-Trichloroethane (methyl chloroform) - HAP	0.48
1,1,2,2-Tetrachloroethane - HAP/VOC	1.1
1,1-Dichloroethane (ethylidene dichloride) - HAP/VOC	2.4
1,1-Dichloroethene (vinylidene chloride) - HAP/VOC	0.20
1,2-Dichloroethane (ethylene dichloride) - HAP/VOC	0.41
1,2-Dichloropropane (propylene dichloride) - HAP/VOC	0.18
2-Propanol (isopropyl alcohol) - VOC	50
Acetone	7
Acrylonitrile - HAP/VOC	6.3
Benzene - No or Unknown Co-disposal - HAP/VOC	1.9
Benzene - Co-disposal - HAP/VOC	11
Bromodichloromethane - VOC	3.1
Butane - VOC	5
Carbon monoxide	140
Carbon tetrachloride - HAP/VOC	0.004
Carbonyl sulfide - HAP/VOC	0.49
Chlorobenzene - HAP/VOC	0.25
Chloroethane (ethyl chloride) - HAP/VOC	1.3
Chloroform - HAP/VOC	0.03
Chloromethane - VOC	1.2
Dichlorobenzene - (HAP for para isomer/VOC)	0.21
Dichlorofluoromethane - VOC	2.6
Dichloromethane (methylene chloride) - HAP	14
Dimethyl sulfide (methyl sulfide) - VOC	7.8
Ethane	890
Ethanol - VOC	27
Ethyl mercaptan (ethanethiol) - VOC	2.3
Ethylbenzene - HAP/VOC	4.6
Ethylene dibromide - HAP/VOC	0.001
Fluorotrichloromethane - VOC	0.76
Hexane - HAP/VOC	6.6
Hydrogen sulfide	36
Mercury (total) - HAP	0.00029
Methyl ethyl ketone - HAP/VOC	7.1

Methyl isobutyl ketone - HAP/VOC	1.9
Methyl mercaptan - VOC	2.5
Pentane - VOC	3.3
Perchloroethylene (tetrachloroethylene) - HAP	3.7
Propane - VOC	11
t-1,2-Dichloroethene - VOC	2.8
Toluene - No or Unknown Co-disposal - HAP/VOC	39
Toluene - Co-disposal - HAP/VOC	2.8
Trichloroethylene (trichloroethene) - HAP/VOC	2.8
Vinyl chloride - HAP/VOC	7.3
Xylenes - HAP/VOC	12

Table 4 demonstrated the amount of methane produced in different years at different period in landfill of Zahedan.

Table 4: Amount of methane produced in different years

years	m^3/hours	years	m^3/hours
2006	105.200	2016	1450.27
2007	213.89	2017	1629.91
2008	326.62	2018	1821.32
2009	443.96	2019	2025.61
2010	566.50	2020	2243.99
2011	695.80	2021	2477.72
2012	829.89	2022	2728.20
2013	972.01	2023	2929.92
2014	1122.25	2024	3258.48
2015	1281.35	2025	3595.63

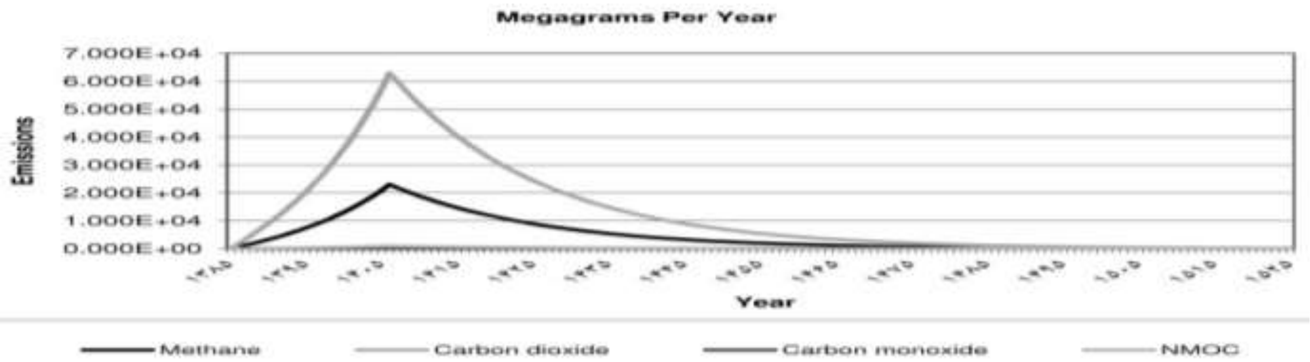

Fig 1: The graph of methane emission (ton/year)

The high percentage of organic compounds in the landfill sites causes the increase of gas generation. As shown in Chart 1, in the first few years of landfill, the gas generation rate is high (steep slope) due to the presence of organic compounds (rapid biodegradable) in the waste.

By accepting new waste and considering the decrease of gas generation in the last waste, the organic compounds biodegradation rate gradually reduced (the decrease of slope). In this case, the presence of older waste in the landfill site adjusts the gas generation rate. In this research, the potential of methane gas generation was calculated and reported about 147 m^3/ton in the Sistan and Baluchistan Province. These results are in agreement with the results of research conducted by Mahvi and coworkers entitled “Calculating the amount of methane gas emission from the waste hygienic burial in Shahrood City using the LandGEM software”. The amount of methane gas annual generation was 138 m^3/h in 2011 using the LandGEM software. This amount was predicted to be 472 m^3/h in 2026, and the amount of methane gas generation with the waste weight of 34167.5 to 61890.4 is 52-488 m^3/h.

In the research carried out by Omrani *et al.* entitled "Technical and health assessment of methane gas extraction in the landfill in Shiraz City", the methane gas generation potential is 164 m^3/ton with the methane generation constant rate of 0.06 (18). The lower amounts of methane gas produced in this research in comparison with the other research can be due to the humidity percent and the difference of types and amounts of organic compounds in the waste.

Conclusion

This study showed that by maintaining the correct design principles of the waste burial, the occurrence of some events such as explosion and fire not only decreases, but also the emission of unpleasant, toxic and pollutant odors in the landfill sites and their around reduces to help the protection of environment in the desired area and the world.

Finally, after the physical and chemical analysis of waste and calculation of above parameters, the potential of methane gas generation (L_0) in the Sistan and Baluchistan Province was calculated about 147 m^3/ton. The methane gas generation rate was 567 m^3/h in 2011, and it will be 3596 567 m^3/h in 2026. Also, it was indicated that during different years, the methane gas generation rate in the Sistan and Baluchistan Province follows the Sheldon-Aleta model, and can be one of the waste management parameters in this province to compensate some costs *via* the energy conversion.

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